

CLAIMS

What is claimed is:

1. Apparatus for automatically selecting one of a standard decision directed (dd) mode and a soft dd mode in a decision feedback equalizer (DFE) for receiving a data signal, said apparatus comprising:

an equalizer (e.g. FIG. 1) having an output for providing a DFE output signal and
5 having a control input responsive to a control signal (**sel**) exhibiting (a) a first value (1) for selecting said standard dd mode and (b) a second value (0) for selecting said soft dd mode;

said equalizer including a lock detector (20) having an output for providing a lock signal (**eq1_lock_int**) indicative of equalizer convergence; and

10 a mode selector (18) having an input coupled to said lock detector output and having an output coupled to said control input for providing a control signal (**sel**) exhibiting one of said first and second values depending upon characteristics of said lock signal.

2. Apparatus in accordance with claim 1, wherein said mode selector includes:

a processor having:

an input coupled to said mode selector input for counting the number of transitions (**NTr**) of said lock signal (**eq1_lock_int**) between said first and second values
5 (1,0) during a defined interval (**W symbol periods**);

a comparator (**:Thr**) for comparing said number of transitions (**NTr**) against a defined threshold count (**Thr**); and

a comparator output providing a first signal (**sel**) exhibiting said first value (1) when said number of transitions is less than said threshold count (**Thr**) and exhibiting

- 10 said second value (0) when said number of transitions is not less than said threshold count (**Thr**), said comparator output being coupled to said mode selector output.
3. Apparatus in accordance with claim 1, wherein said mode selector (18) includes a second output for selectively placing said DFE output in one of:
- (a) one of a standard dd mode and a soft dd mode, and
 - (b) a blind mode, depending upon characteristics of said lock signal
- 5 (**eql_lock_int**).
4. Apparatus in accordance with claim 3, wherein
- said second mode selector output selectively places said DFE output in blind mode when said lock signal output indicates no convergence, and
- places said DFE output in one of said dd modes when said lock signal output
- 5 detects one of convergence or unstable convergence, with a decision as to which dd mode is selected being controlled by said first mode selector output (**sel**).
5. Apparatus in accordance with claim 1, wherein said mode selector (18) includes a second output for selectively placing said DFE output in one of:
- (a) one of a standard dd mode and a soft dd mode, and
 - (b) a training mode, depending upon characteristics of said lock signal
- 5 (**eql_lock_int**).
6. Apparatus in accordance with claim 5, wherein
- said second mode selector output selectively places said DFE output in training mode when said lock signal output indicates no convergence, and

places said DFE output in one of said dd modes when said lock signal output
5 detects one of convergence or unstable convergence, with a decision as to which dd mode
is selected being controlled by said first mode selector output (sel).

7. Apparatus in accordance with claim 2, wherein said defined interval (**W symbol periods**) corresponds to a period of a defined number (**W**) of symbol time periods of said data signal.

8. Apparatus in accordance with claim 7, wherein said defined interval (**W symbol periods**) and said defined threshold count (**Thr**) are programmable variables.

9. Apparatus in accordance with claim 8, wherein said processor includes:

a transition detector including a first D-flip-flop (**FF1**) for outputting a delayed version of said lock signal;

an exclusive-OR gate (**XOR**) coupled to said lock signal (**eq1_lock_int**) and to
5 said delayed version (**Q**) for providing a transition-indicating signal, said transition-indicating signal exhibiting a count of **NTr** for said defined counting interval;

a count comparator (**:Thr**) for comparing said count of **NTr** against said threshold count for providing said first signal (**sel**).

10. Apparatus in accordance with claim 6, wherein said comparator output (**sel**) is coupled to said mode selector output by way of a state machine (Fig. 8) including:

apparatus (**state machine**) for counting, during a period of a given number of symbol periods (**N*W**) of said data signal, the number of occurrences of said first level of
5 said first signal (**sel=1**) for providing a second signal, wherein:

(a) if said equalizer is in said first mode and said number of occurrences of said first level is not less than a given threshold count (**sel_thr**), said second signal exhibits said first value (1), and

10 (b) if said equalizer is in said second mode and said number of occurrences of said first level (1) is less than said given threshold count (**sel_thr**), said second signal exhibits said second value (0).

11. Apparatus in accordance with claim 9, wherein said given number of symbol periods (**N*W**) and said threshold count (**sel_thr**) are programmable variables.

12. Apparatus for automatic selection of one of a standard automatic switching mode and an automatic switching mode in a decision feedback equalizer (DFE) for receiving a data signal, said equalizer including a lock detector (20) for providing a lock signal (Lock Output) indicative of equalizer convergence, and wherein said selection is based on
5 monitoring of the rate of transitions of said lock signal.

13. Apparatus in accordance with claim 12, wherein said selection is based on whether said rate of transitions is less than or not less than a prescribed rate (**Thr**).

14. Apparatus in accordance with claim 13, wherein:

when said rate of transitions is less than said prescribed rate (**Thr**), said standard automatic switching mode is selected; and

5 when said rate of transitions is not less than said prescribed rate (**Thr**), said soft automatic switching mode is selected.

15. Apparatus in accordance with claim 13, wherein said prescribed rate (**Thr**) is defined as a threshold count of transitions within a window period (**N** periods of **W** symbols).

16. Apparatus in accordance with claim 15, wherein said window period (**N** periods of **W** symbols) is defined in terms of symbol counts of said data signal.

17. Apparatus in accordance with claim 16, wherein said window period (**N** periods of **W** symbols) and said threshold count are programmable variables.

18. Apparatus in accordance with claim 12, wherein said selection is further based on:
taking account of which mode is presently selected; and
the rate of lock signal (**eql_lock_int**) occurrences (**sel count**) for setting said standard automatic switching mode as compared with a given threshold occurrence rate (**sel_thr**).

19. Apparatus in accordance with claim 18, wherein:

when said standard dd mode is presently selected and said rate of lock signal occurrences (**sel count**) for setting said standard dd mode is less than said given threshold occurrence rate (**sel_thr**), said soft dd mode is selected;

otherwise, when said rate of lock signal occurrences (**sel count**) is not less than said given threshold occurrence rate (**sel_thr**), said standard dd mode remains selected;

when said soft dd mode is presently selected and said rate of lock signal occurrences (**sel count**) for setting said standard dd mode is not less than said given threshold occurrence rate (**sel_thr**), said standard dd mode is selected; and

10 otherwise, when said rate of lock signal occurrences (**sel count**) is less than said given threshold occurrence rate (**sel_thr**), said soft dd mode remains selected.

20. Apparatus in accordance with claim 18, wherein said given threshold occurrence rate (**sel count**) is defined in terms of a threshold number (**sel_thr**) of said lock signal occurrences within a period of a defined number **N** of symbol counts **W** of said data signal.

21. Apparatus for automatic selection of one of a standard automatic switching mode and a soft automatic switching mode in a decision feedback equalizer (DFE) for receiving a data signal, wherein

said automatic switching mode comprises one of:

- 5 (a) a blind mode, and
 (b) a decision directed mode, and

said soft automatic switching mode comprises one of:

- (a) a blind mode, and
 (b) a soft decision directed mode;

10 said equalizer having a control input for mode selection responsive to a signal (**sel**) exhibiting:

- (a) a first value (1) for selecting said standard automatic switching mode, and
 (b) a second value (0) for selecting said soft automatic switching mode, and
including a lock detector (20) for providing a lock signal (**Lock Output**) having first and
15 second lock signal values (1,0) respectively indicative of equalizer convergence and non-convergence; and

apparatus for providing a selection signal (**sel**) to said control input for mode selection, said apparatus:

- 20 monitoring the rate of transitions (**NTr**) of said lock signal between said first and second lock signal values (1,0) and providing a control signal (**sel**);
- 25 comparing said rate of transitions (**NTr**) with a threshold rate of transitions (**Thr**) and causing said control signal (**eq1_mode_sel**) to exhibit a first control value (1) when said rate of transitions is less than said threshold rate and to exhibit said second value (0) when said rate of transitions is not less than said threshold rate (**Thr**);
- 30 when said equalizer is in said standard automatic switching mode, monitoring the rate of occurrences of said control signal (**sel**) having said first control value (1) and comparing said rate with a threshold rate of occurrence (**sel_thr**) and if said rate of occurrences is less than said threshold rate of occurrence (**sel_thr**) then causing said selection signal to exhibit said second value (0) for selecting said soft automatic switching mode;
- 35 otherwise, when said rate of occurrences is not less than said threshold rate of occurrence (**sel_thr**), said standard automatic switching mode remains selected, and
- 40 when said equalizer is in said soft automatic switching mode, monitoring the rate of occurrences of said control signal (**sel**) having said first control value (1) and comparing said rate with said threshold rate of occurrence and if said rate of occurrences is not less than said threshold rate of occurrence (**sel_thr**) then causing said selection signal (**eq1_mode_sel**) to exhibit said first value (1) for selecting said standard automatic switching mode, and

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45 otherwise, when said rate of occurrences is less than said threshold rate
(**sel_thr**), said soft automatic switching mode remains selected.

22. Apparatus for automatic selection of one of a standard automatic switching mode and a soft automatic switching mode in a decision feedback equalizer (DFE) for a data signal, wherein said automatic switching mode comprises a blind or decision directed mode and said soft automatic switching mode comprises a blind or soft decision directed mode, said apparatus comprising:

5 means for monitoring (FF1,XOR, COUNTER 1, COUNTER 2, FF2) transitions
(**NTr**) of a lock signal indicative of equalizer convergence;

means for comparing (:Thr) the rate of said transitions against a prescribed rate
(**Thr**);

10 means for providing a control signal (**sel**) exhibiting:

a first control value (1) associated with said standard automatic switching mode when said rate of transitions is less than said prescribed rate (**Thr**) and exhibiting a second control value (2) associated with said soft automatic switching mode when said rate of transitions (**NTr**) is not less
15 than said prescribed rate(**Thr**); and

means for counting (state machine), during a period of a given number (**N*W**) of symbol periods of said data signal, the number of occurrences (**sel_count**) of said first control value (1) of said control signal and if:

20 said equalizer is in said first mode and said number of occurrences (**sel_count**) of said first control value (1) is less than a given threshold count (**sel_thr**), said means selects said soft automatic switching mode, otherwise, said means selects said standard automatic switching mode, and if:

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25 said equalizer is in said second mode and said number of occurrences (**sel_count**) of said first level (1) is not less than said given threshold count, said means selects said standard automatic switching mode, otherwise, said means selects said soft automatic switching mode.

23. Apparatus for automatic selection of one of a standard automatic switching mode and a soft automatic switching mode in a decision feedback equalizer (DFE) (Fig. 1) for a data signal, wherein said automatic switching mode comprises a blind or decision directed mode and said soft automatic switching mode comprises a blind or soft decision directed mode, and the apparatus comprising:

5 said DFE having a control input for selecting said modes;

 means for monitoring (FF1,XOR, COUNTER 1, COUNTER 2, FF2) transitions (**NTr**) of a lock signal (Lock output) indicative of equalizer convergence;

 means for comparing (**:Thr**) the rate of said transitions (**NTr**) against a prescribed rate (**Thr**);

10 means (state machine) for providing a selection signal (**sel**) to said control input exhibiting a first value (1) for selecting said standard automatic switching mode when said rate of transitions (**NTr**) is less than said prescribed rate (**Thr**) and exhibiting a second value (0) for selecting said soft automatic switching mode when said rate of

15 transitions (**NTr**) is not less than said prescribed rate (**Thr**).

24. Apparatus for automatically selecting one of a standard decision directed (**dd**) mode and a soft **dd** mode in a decision feedback equalizer (DFE) for receiving a data signal, said apparatus comprising:

5 means for determining the rate of transitions between first and second values of a lock signal indicative of convergence;

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means for comparing said rate of transitions against a defined threshold rate (Thr); and

means for providing a first control signal (sel) exhibiting a first value (1) when said rate of transitions is less than said threshold count and exhibiting a second value (0) when said rate of transitions is not less than said threshold count; and

means for providing a coupling between said first control signal and a mode selector input of said DFE, said first standard (dd) mode being selected when a signal at said mode selector input exhibits a first value and said soft dd mode being selected when a signal at said mode selector input exhibits a second value.

25. Apparatus in accordance with claim 24, wherein said means for providing a coupling between said first control signal and a mode selector comprises:

means for determining the rate of occurrences of said first value of said first control signal (state machine) for providing a second control signal (eql_mode_sel);

means for comparing said rate of occurrences (state machine) of said first value (1) of said first control signal to a given rate of occurrence (sel_thr);

means (state machine) for causing said second control signal to exhibit a first given value (1) if said equalizer is in said first mode and said rate of occurrences (sel count) of said first level (1) of said first control signal is not less than a given threshold count (sel_thr), otherwise, the second control signal (eql_mode_sel) exhibits a second given value (0);

means for causing said second control signal (eql_mode_sel) to exhibit said second given value (0) if said equalizer is in said second mode and said rate of occurrences of said first level is not less than said given threshold count (sel_thr), otherwise, the second control signal exhibits said first given value; and

means for coupling said second signal to said mode selector input.

26. A method for automatic selection of one of a standard automatic switching mode and a soft automatic switching mode in a decision feedback equalizer (DFE) for receiving a data signal, comprising the steps of:

monitoring transitions of lock signal indicative of equalizer convergence;

5 comparing the rate of said transitions against a prescribed rate;

providing a selection signal exhibiting a first value (1) for selecting said standard automatic switching mode when said rate of transitions is less than said prescribed rate and exhibiting a second value (0) for selecting said soft automatic switching mode when said rate of transitions is not less than said prescribed rate.

27. A method for automatic selection of one of a standard automatic switching mode and a soft automatic switching mode in a decision feedback equalizer (DFE) for receiving a data signal, comprising the steps of:

monitoring transitions of a lock signal indicative of equalizer convergence;

5 comparing the rate of said transitions against a prescribed rate;

providing a selection signal exhibiting a first value when said rate of transitions is less than said prescribed rate and exhibiting a second value when said rate of transitions is not less than said prescribed rate;

10 counting, during a period of a given number of symbol periods of said data signal, the number of occurrences of said first value of said first signal;

if said equalizer is in said first mode and said number of occurrences of said first value is not less than a given threshold count, selecting said standard automatic switching mode, otherwise, selecting soft automatic switching mode; and

15 if said equalizer is in said second mode and said number of occurrences of said first level is not less than said given threshold count, selecting said standard automatic switching mode, otherwise, selecting soft automatic switching mode.

28. A method for automatically selecting one of a standard automatic switching mode and a soft automatic switching mode in a decision feedback equalizer (DFE) for receiving a data signal, comprising the steps of:

5 determining the rate of transitions between first and second values of a lock signal indicative of convergence;

comparing said rate of transitions against a defined threshold rate;

providing a first signal exhibiting a first given value when said number of transitions is less than said threshold count and exhibiting a second given value when said number of transitions is not less than said threshold count; and

10 providing a coupling between said first signal and a mode selector input of said DFE, said first standard automatic switching mode being selected when a signal at said mode selector input exhibits said first given value and said soft automatic switching mode being selected when a signal at said mode selector input exhibits a said second given value.

29. A method in accordance with claim 28, wherein said step of providing a coupling between said first signal and a mode selector comprises the steps of:

determining the rate of occurrences of said first value of said first signal;

5 comparing said rate of occurrences of said first value of said first signal against a threshold;

if said equalizer is in said first mode and said number of occurrences of said first level is not less than a given threshold count, causing a second signal to exhibit said first given value, otherwise, said second signal exhibits said second value;

- 10 if said equalizer is in said second mode and said number of occurrences of said first level is not less than said given threshold count, causing said second signal to exhibit said first given value, otherwise, said second signal exhibits said second value; and
coupling said second signal to said mode selector input.